MANUAL OF INSTRUCTION

FOR THE

RF VOLTAGE STANDARD

TYPE 245-A

MP MASTER
MA24346

BOONTON RADIO CORPORATION
BOONTON, NEW JERSEY
U. S. A.

7-55

Printed in U.S.A.

NOTICE OF CHANGES

On Serial Number 40 and above, the nominal value of the input impedance at the BNC connector on the Input Cable is 50 Ω and the maximum input VSWR is 1.2 between 0.1 MC and 250 MC., rising to 1.4 at 500 MC.

The 50 Ω nominal characteristic impedance of the input cable is terminated by the parallel combination of the 60 Ω coaxial attenuator impedance and the 300 Ω diode voltmeter impedance.

INPUT CABLE VSWR

Change 1.50 to "1.2 between 0.1 MC and 250 MC rising to 1.4 at 500 MC." (P5, L14)

INPUT CABLE

The Input Cable is double-shielded with 50 Ω characteristic impedance, instead of RG-55/u. (P7, L6).

ATTENUATOR INPUT RESISTOR

Change 50 Ω to 60 Ω; P15, L2; P15, L20; P15, L24; P16, Fig 1V-1, input resistor; P22, R9 becomes 60 Ω (A80728).

ATTENUATOR DISC RESISTOR

Change 0.002 Ω to 0.0024 Ω: P15, L3; P15, L6; P15, L25; P16, Fig. 1V-1, dis resistor; P22, R10

P16, L1 Change "an identical" to "a similar."

See inside rear cover for additions to text.

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TYPE 245-A

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BOONTON, NEW JERSEY
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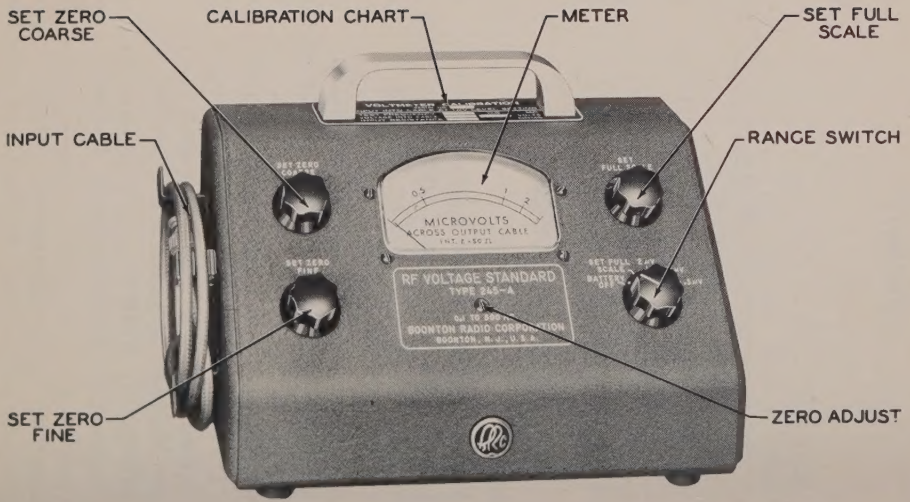


Fig. 1-1. Front Panel Control Layout.

SECTION I
DESCRIPTION

A. DESCRIPTION

The 245-A Voltage Standard is a fixed precision attenuator equipped with its own input voltage monitor. It primarily is designed as a standard source of microvolt level voltage for the calibration of receivers. The receivers in turn can be used to check or set up variable signal generator output attenuators at fixed points.

B. SPECIFICATIONS

Frequency Range: 0.1 - 500 MC
Output Voltage: 2, 1, 0.5 microvolts open circuit at output cable.
Output Impedance: 50 ohms looking into output cable
Overall accuracy of output voltage: ± 10%
Input cable VSWR: 1.50
VSWR at output connector: 1.05
VSWR at output cable: 1.07

C. FRONT PANEL CONTROLS AND INDICATORS

(1) RANGE SWITCH: The five position range switch (S1) is used to chose the various functions of the instrument. The positions are:

a) *BATTERY OFF*—The internal battery is disconnected and no current will pass through the meter. It is in this position that the mechanical zero of the meter should be checked and corrected if necessary.

b) *SET FULL SCALE*—The instrument should be adjusted for exactly full scale meter reading.

c) *2 MICROVOLTS*—In this position the metering circuit is calibrated using the 2 microvolt output position on the meter.

d) *1 MICROVOLT*—In this position the metering cir-

cuit is calibrated using the 1 microvolt output position on the meter.

e) *0.5 MICROVOLT*—In this position the metering circuit is calibrated using the 0.5 microvolt output position on the meter.

(2) ZERO SET: coarse and fine.

The COARSE ZERO SET is in the upper left hand corner of the front panel and the FINE ZERO SET is in the lower left hand corner of the panel.

The function of these two controls is to cause the meter to read zero with no signal being applied to the input cable. The controls function only when the range switch is set to 2 MICROVOLTS, 1 MICROVOLT or 0.5 MICROVOLT. Clock wise motion of the controls causes the pointer to move to the right. The coarse potentiometer will cause approximately 10 times the displacement of the fine potentiometer.

(3) THE PANEL METER has 5 calibrated points on it:

ZERO, which is the extreme left hand line
FULL SCALE, which is the extreme right hand line
0.5 microvolt, which is at 1/4 of full scale
1.0 microvolt, which is at 3/4 of full scale
2.0 microvolts, which is at 7/8 of full scale.

(4) THE INPUT VOLTMETER DATA PLATE is found on top of the instrument under the handle. It contains the following information:

The serial number of the instrument
The input voltage for 1.0 microvolt output at 0.5 MC.
The input voltage for 1.0 microvolt output at approximately 100 MC. The EXACT Frequency at which the input impedance is a pure resistance is specified for each instrument.
The input resistance at approximately 100 MC.

(5) SET FULL SCALE CONTROL: This control is in the

upper right hand corner of the front panel. It is used to adjust the instrument for exactly full scale meter reading when the range switch is at SET FULL SCALE position. Clockwise motion of the control causes the pointer to move to the right.

D. INPUT CONNECTION

The input is through a 36 inch length of RG 55/U cable which has a BNC Plug at its input end. The cable is an integral part of the case and is permanently attached through the left hand side of the instrument. A bracket is provided for coiling of this cable on the left side of the instrument.

E. OUTPUT CONNECTION

(1) OUTPUT JACK: the output which is equivalent to the output of any BRC signal generator is brought out through a BNC jack on the right hand side of the instrument.

(2) OUTPUT CABLE: A detachable output cable is provided with the instrument. It has a BNC plug on one end, which is intended to connect to the output jack on the side of the cabinet. At the other end is a 50 ohm probe with a BNC jack on it. This should connect to the receiver input. A bracket is provided for the coiling of the output cable on the rear of the instrument.

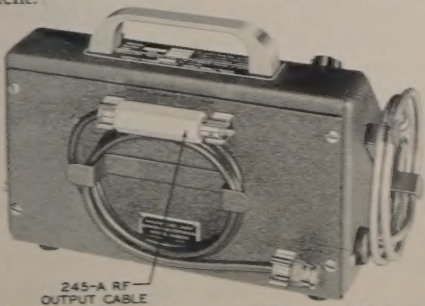


Fig. I-2. Location of RF Output Cable.

SECTION II
OPERATION

A. PREPARATION FOR USE

(1) The RF Voltage Standard has been carefully packed and should be carefully inspected upon receipt for possible physical damage incurred in shipment. Any such damage should be reported immediately to Boonton Radio Corporation.

(2) The instrument is ready for use as soon as it is removed from the shipping container. It is powered exclusively by its internal battery and requires no external power.

B. PRELIMINARY PROCEDURE

(1) If necessary, the mechanical zero of the voltmeter should be adjusted before turning the power on.

(2) Turn the selector switch to SET FULL SCALE and use the SET FULL SCALE control to set the pointer at full scale. CW rotation will move the needle to the right.

(3) Plug the input cable into the output of the signal generator to be used. For the best accuracy the signal generator should have a 50 ohm dc output resistance. With the signal generator output at zero, or less than a millivolt, switch the selector to the output voltage range which is to be used. By means of the ZERO SET knobs, set the meter on zero.

(4) Increase the signal generator output until the meter pointer reaches the point on the scale which corresponds to the switch range in use. With this condition met, the open circuit voltage at the end of the output cable will be what the meter reads, if the output cable is attached. If the output cable is not attached the voltage at the jack on the side of the instrument will be twice the indicated voltage.

C. MEASUREMENT PROCEDURE

(1) In order to use the RF Voltage Standard type 245-A to calibrate the output of a signal generator attenuator, a receiver

must be used as a transfer indicator to compare the signal generator output to the Standard Output of the 245-A. The receiver must have good sensitivity, some type of carrier level meter which can be used as a calibrated reference, and must remain stable in frequency and sensitivity on a short term basis.

(2) With the 245-A adjusted to give the desired output, connect the output cable from the output jack of the 245-A to the antenna input. Peak the receiver and note the output meter reading. (Fig. II-1.)

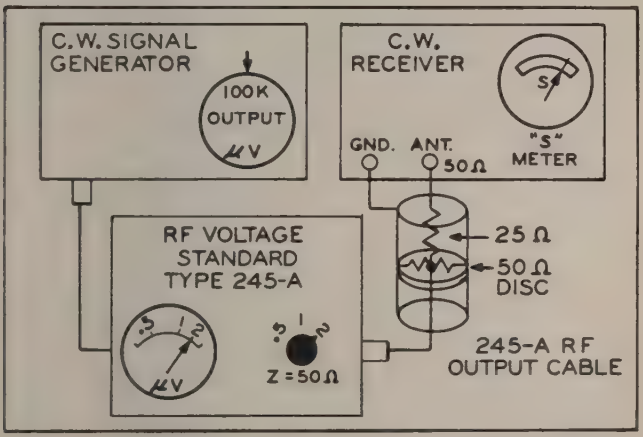


Fig. II-1. Setting Up Receiver For Use As A Transfer Indicator.

(3) Without changing the frequency of the receiver or the signal generator, turn the signal generator output down to minimum and switch the output cable from the 245-A output to the signal generator output. (Fig. II-2.)

(4) Turn the signal generator attenuator up until the re-

ceiver output meter reads the same as it had previously. The signal generator is now putting out the same level established by the 245-A. The signal generator may require retuning to produce maximum output from the receiver. *In no case should the receiver be retuned.*

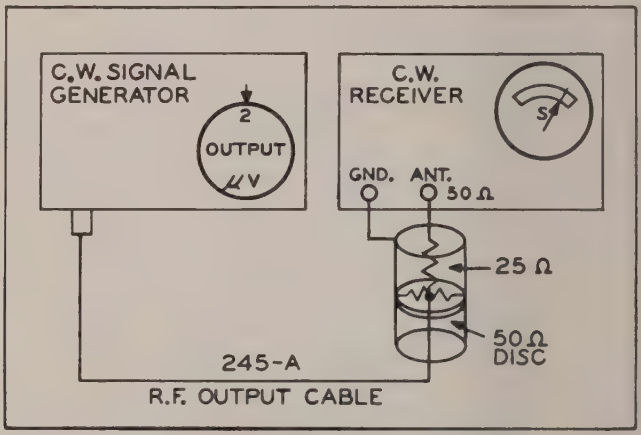


Fig. II-2. Adjusting Signal Generator Output To Pre-Determined Reference Level on "S" Meter.

SECTION III
INTERPRETATION OF RESULTS

A. SIGNIFICANCE OF OUTPUT READING

The voltage which is read on the meter is the open circuit voltage from the RF output cable. The actual voltage produced from the attenuator in the 245-A is 2 times the voltage on the meter. With 50 ohms at the end of the output cable the 2E divides equally between the internal 50 ohms and the external 50 ohms. This leaves E across the 50 ohms in the probe.

Looking back from the external circuit both 50 ohm resistors appear in parallel as 25 ohms, therefore, the RF output cable has a 25 ohm resistor in series with the output jack. This makes the output impedance equal to 50 ohms as shown in Fig. III-1.

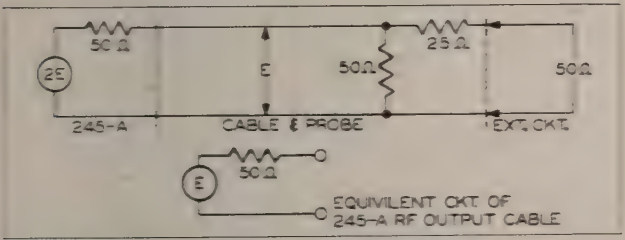


Fig. III-1. RF Output Cable And Probe, Basic Circuit.

B. SOURCES OF ERROR IN TRANSFER

(1) IMPEDANCE MISMATCH. One source of error in this type of transfer measurement is the impedance of the generator output system. The output of the 245-A is 50 ohms. If the internal impedance of the generator under test is not 50 ohms, the generated voltage will not divide equally between

the internal impedance and the shunt 50 ohms in the probe. This then will not indicate truly the point at which the generator and the standard are equivalent.

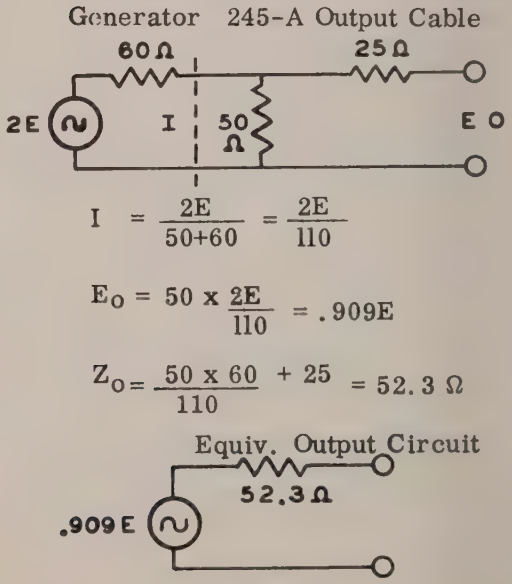


Fig. III-2. Example: Generator Z_O=60 Ω

Besides the apparent effect on the open circuit voltage a standing wave will be induced on the line as soon as the probe is loaded. This is of no consequence if the line is terminated in its Zo at the generator end, but if the generator impedance is not 50 ohms this standing wave will cause an error which is variable with frequency.

(2) NOISE-BANDWIDTH: A secondary source of error is also caused by the output impedance of the generator. If a broad band system is used as a detector, the effective thermal noise output of the generator calibrator source impedance can be of a significant magnitude. For example, if the detector system has a 1 MC band width, a 50 ohm output impedance would generate 0.897 μV. If the output impedance were changed to 52.3 ohms, the thermal noise would be 0.918 μV, or 2.3% error. The noise level is of course, proportional to the band width, and would be negligible in a normal receiver.

(3) GENERATOR DC RESISTANCE: The DC resistance of the signal generator used to drive the 245-A is part of the dc current return path for the diode voltmeter. The instrument is calibrated for operation with a generator having 50 ohms dc resistance. This value need not be held to close limits but radical departures from 50 ohms, such as O or infinity can cause as much as 5% error in the voltmeter calibration. It is generally true, however, that the output impedance and the DC resistance are the same in a signal generator output and the necessity of a 50 ohm output has already been emphasized.

(4) GENERATOR LEAKAGE: Leakage from the generator being used with the 245-A could cause a serious error in the results. Any signal entering the receiver input from the generator which did not come through the 245-A attenuator system would make the receiver read higher and give an improper reference. If this leakage is independent of the signal generator attenuator setting, a simple test can be made.

With the signal generator feeding the 245-A which in turn feeds the receiver, reduce the generator output to a minimum. Then shift the generator frequency. If shifting the frequency does not affect the "S" meter, leakage is probably not present. Some generators, however, may leak only when the attenuator is turned near maximum output and this would not be revealed by such a simple check.

If the receiver in use is well shielded and has a coaxial antenna input, it is not likely that generator leakage would get into the receiver. If the signal generator is known to have a troublesome degree of leakage, either it must be better shielded or the receiver input must be better shielded, or both.

The input cable of the 245-A has double-shielded coaxial cable because it has been found that single shielded cable allows excessive leakage. If it is necessary to use a longer extension to connect to the input cable, a double shielded cable should certainly be used.

(5) DISTORTION: An error can be expected if the Signal Generator in use has a high percentage of distortion or other spurious signals. The voltmeter of the 245-A will measure the total power and not just the power in the desired carrier. However, it would be meaningless to accurately calibrate a highly distorted voltage, and it should be sufficient to say that the signal being calibrated must be reasonably clean.

SECTION IV
THEORY OF OPERATION

A. MICROPOTENTIOMETER TYPE ATTENUATOR

The basic attenuator system is a 50 ohm resistor in series with a .002 ohm resistor. This gives a voltage division of 25,000:1. There is a 50 ohm resistor in series with the output to give a 50 ohm output impedance.

The .002 ohm resistor is a concentric disc resistor made up of a very thin film of silver on a ceramic disc. The disc resistor element is approximately 40×10^{-6} inches thick and is therefore less than half the thickness of the skin depth at 1000 MC. As a result of this characteristic, the current always flows uniformly through the film from d.c. up to 1000 MC, and the series resistance of the disc measured at dc will be the same at all frequencies in the range of the instrument. The concentric construction of the disc assures a minimum value of series inductance and for all practical purposes the resistance at dc and 1000 MC are the same. A thorough discussion of this type of element is given in a paper by M. C. Selby of the National Bureau of Standards.*

B. RF RESISTORS IN UNIFORM TRANSMISSION LINE

The 50 ohm series resistor is a very thin evaporated metal film on a glass rod. This is enclosed in a metal tube of a suitable diameter. It can be considered a coaxial transmission line whose center conductor is resistive. By using the proper design constants this line will be 50 ohms, and have a very low VSWR up to 1000 MC.† The .002 ohm disc resistor is placed as a short circuit at the end of the line.

*"Accurate Radio Frequency Microvoltages," M. C. Selby—Transactions AIEE, May 1953.

The output section is an identical coaxial section on the output side of the disc.

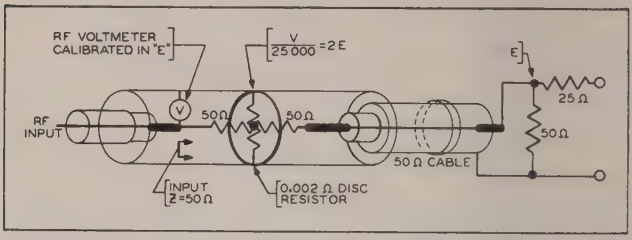


Fig. IV-1. RF Voltage Monitor And Control Attenuator System.

C. BIASED DIODE VOLTMETER

The input voltage to the attenuator is monitored by a diode voltmeter. The diode is a 1N173 uhf mixer diode. In order that the rectification characteristics of the diode remain stable, a nominal bias current of 100 microamperes is maintained through the diode in the no signal condition. This has the effect of fixing a definite operating point on the diode characteristic curve which will always have the same rectification efficiency.

D. TRANSISTOR IMPEDANCE TRANSFORMER

The biased diode presents such a low impedance to the 20 microampere meter movement that the meter would move at a sluggish rate if an impedance matching device of at least 40,000 ohms were not interposed between diode and meter. A common base transistor amplifier is used in the 245-A for this purpose. This amplifier has a current gain of about 0.98. The result is that the crystal works into a suitably low resistance and the meter sees only a high impedance.

†"Radio Frequency Resistors As Uniform Transmission Lines," D. R. Crosby and C. H. Pennypacker—Proc. IRE, Feb. 1946, p. 62P.

The factor α of the transistor determines the gain and this in itself is a very stable characteristic which changes only minutely with temperature. The transitor is hermetrically sealed and free from any atmospheric influence.

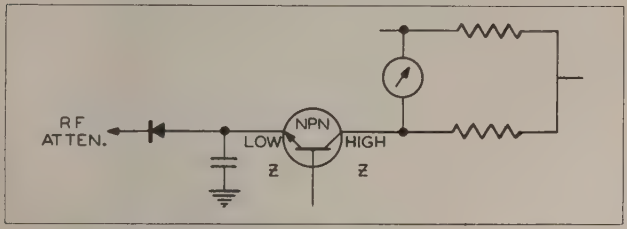


Fig. IV-2. Transistor As Impedance Transformer.

E. DC METERING CIRCUIT AND ADJUSTMENTS

In order to realize the greatest calibration accuracy there is only one calibrated point on each range. This allows the use of separately adjustable trimming resistors to bring the meter multiplier on each range to the exact value regardless of the individual meter nonlinearity and attenuator variations.

SECTION V
MAINTENANCE AND CALIBRATION

A. INPUT VOLTMETER CALIBRATION

Should it be necessary to check the input voltmeter, the input voltage to the cable is given for the 1 microvolt range. This information appears on the top plate of the instrument. It is best that the check be made near 0.5 MC as noted on the plate. At frequencies lower than 0.1 MC, the voltmeter bypassing is inadequate and at higher frequencies, the presence of standing waves will result in an unreliable indication of the voltage at the other end of the cable. The voltage given is the voltage required at the input to the attenuator section in order to bring the meter from zero to 1.0 microvolt. If one desires to check 2 microvolt or $\frac{1}{2}$ microvolt, the voltages required are respectively 2 times or $\frac{1}{2}$ the microvolt value.

If an audio voltmeter is to be used which is not accurate to 100 KC, it is possible to check at lower frequencies by providing additional bypassing. To do so, remove the four screws which hold the rear cover on and remove the rear cover. Connect approximately 20 - 30 μf from the yellow wire with green tracer to ground. This wire is connected to the right end of the RF block assembly. This degree of bypassing is adequate to less than 1000 cps.

The input voltage to the cable is also given at an indicated frequency near 100 MC. This frequency is chosen as the frequency where the input cable is approximately $\frac{1}{2}$ wave length long and the input impedance is resistance only. The impedance which is given is that resistance which is read by the Boonton Radio 250-A RX Meter with a 515-A Coaxial Adapter properly installed.

B. BATTERY REPLACEMENT

When the point is reached where it is no longer possible

to adjust the meter to full scale in SET FULL SCALE position, it will be necessary to replace the batteries.

Remove the rear cover by removing the four screws which are in the corners of the rear cover. The batteries are mounted in clips on the back cover. They can be removed with the fingers once the keeper plate has been taken off. The keeper plate is held down by two elastic stop nuts.

The two new batteries (General - 696) can be pushed into the clips with the fingers. The positive end of the battery contacts the end with the red wire attached.

Replace the keeper plate and screw down the two elastic stop nuts. Tighten these only firmly enough to prevent looseness. Do not crush the batteries.

Replace the rear cover, being sure that it is right side up, and that the battery wires are not crushed.

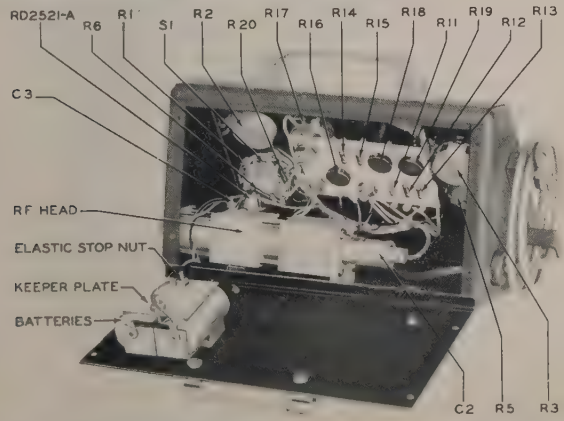


Fig. V-1. Interior View – Component layout, including mounting of batteries.

SECTION VI
EXTENSION OF RANGES

A. USE OF PADS

If accurate 50 ohm pads are available it is possible to extend the effective microvolt range of the instrument in either direction with the aid of a suitable resistor.

In order to use the 245-A to calibrate a point which is higher in voltage than the instrument puts out it is necessary only to put a pad of suitable attenuation in series with the signal generator to be calibrated. This serves to attenuate the higher level of the signal generator by a known ratio to one of the output values of the 245-A. The procedure would be the same as in section C with the exception that when the output cable is switched from the 245-A to the signal generator output jack a suitable pad must be inserted in this lead.

The extension of the 245-A output range downward is readily accomplished by connecting a suitable pad to the output jack of the 245-A when it is in use. This practice, however, puts severe requirements on the leakage out of the generator. One must be careful to check the generator leakage in order to be sure that more voltage is not getting into the receiver than comes through the 245-A.

B. USE WITH AM GENERATOR

In some cases it may not be possible to obtain a receiver with a meter which indicates relative signal strength. In this case an AC meter may be used to indicate the audio output of an AM receiver with AM modulation placed on the carrier in use. Providing the modulation is held constant and the receiver is reliably stable, this indication of audio output can be used to indicate relative signal strength.

There is one precaution in the use of modulation with the 245-A. The diode voltmeter is a square law detector and re-

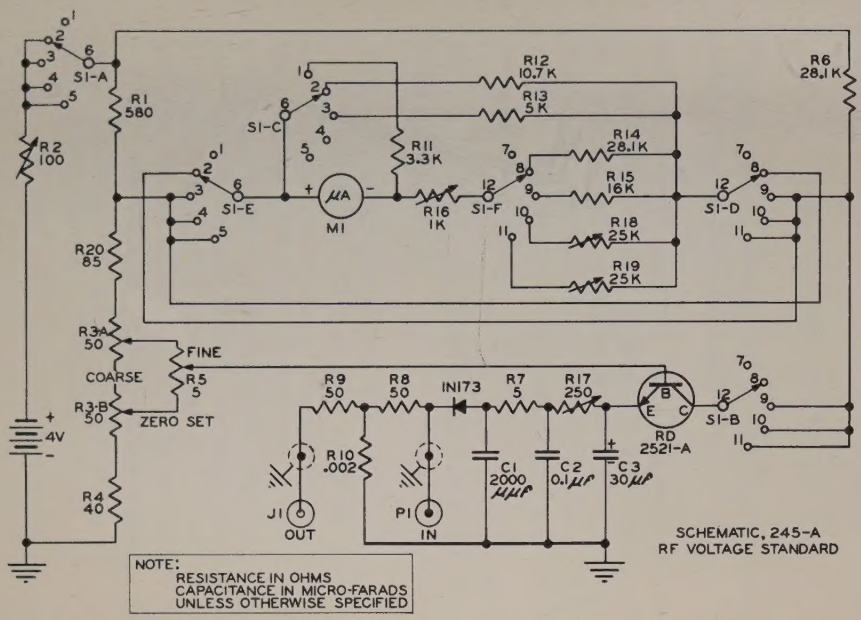
sponds to total power. When the carrier is modulated its power is increased and the meter on the 245-A will read higher than it should. For low percentages this is negligible as shown in Chart #1.

Percent Modulation	Percent Error
10	0.2
20	0.9
30	2.0
40	3.8
50	6.0
60	8.5

ELECTRICAL

ELECTRICAL PARTS RF VOLTAGE STANDARD 245-A

Circuit Symbol	Value	Description	BRC Part No.
R1	580Ω	Res. Fixed 1/2W ± 1%	80169
R2	100Ω	Res. Var. ±10%	A 81031
R3	5Ω	Res. Var. Dual	A 81029
R4	40.0Ω	Res. Fixed 1/2W ±1%	80132
R5	5Ω	Res. Var.	A 80130
R6	28.1KΩ	Res. Fixed 1/2W ±1%	80400
R7	5Ω	Res. Fixed 1/4W ±5%	80047
R8	50Ω	Res. Fixed 1/2W ±1% no spiral, EC coat	80050
R9	50Ω	Res. Fixed 1/2W±1%	A 80050
R10	.002Ω	Res. Fixed Ceramic Disc	A303433
R11	3300Ω	Res. Fixed1/2W ±10%	80280
R12	10.7KΩ	Res. Fixed 1/2W ±1%	80319
R13	5 KΩ	Res. Fixed 1/2W ±1%	80302
R14	28.1KΩ	Res. Fixed 1/2W ±1%	80400
R15	16KΩ	Res. Fixed 1/2W ± 1%	80323
R16	1KΩ	Res. Var.	A 81121
R17	250Ω	Res. Var.	A 81127
R18	25KΩ	Res. Var.	A 81420
R19	25KΩ	Res. Var.	A 81420
R20	85.0Ω	Res. Fixed 1/2W ±1%	80134
C1	2000uuf	Cap. Fixed Silver Button Mica	82319
C2	.1μμf	Cap. Fixed 250VAC	83096
C3	30μf	Cap. Fixed 6WV	83098
S1		Switch, Rotary	A303355
M1			
M1	0-20MA	Meter	B303325
		Transistor RD2521A	303425
		1N173 Mixer Diode	303454
		Mercury Battery, 3.9 Volt (3 RG-3 in series in sleeve) 1 Dia. x 1.960 Long (2) Reqd.	303440



SCHEMATIC DIAGRAM- VOLTAGE STANDARD TYPE 245-A

NOTES

ADDITIONS TO TEXT

The following information should be inserted in the text at the position shown

P11, L5- "....meter. The terminating section of the Output Cable contains a 50 Ω shunt terminating resistor followed by a 25 Ω impedance matching resistor in series with the BNC connector, to which the External Circuit load is connected. With....."

P11, L7 - "....probe with the External Circuit load open circuit."

P18 (following paragraph 2):

The instrument can be used as a voltmeter at higher frequencies. The characteristic impedance of the cable and the diode varies somewhat and the resulting standing wave applies across the diode a voltage which, in general, differs from that applied at the input to the cable. The voltage shown on the Data Plate will be within ±10% of the voltage applied at the input to the Input Cable from 0.1 MC to 250 MC, and within ±20% from 250 MC to 500 MC."

MP MASTER
MA24346